SUSPENDED-SLURRY REACTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Ser. No. 61/593,486, filed Feb. 1, 2012, titled "SUSPENDED-SLURRY REACTOR CONCEPT," hereby incorporated by reference in its entirety for all of its teachings.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

The invention was made with Government support under Contract DE-AC05-76RLO1830, awarded by the U.S. Department of Energy. The Government has certain rights in the invention.

TECHNICAL FIELD

This invention relates to heterogeneous chemical reactors. More specifically, this invention relates to suspended-slurry chemical reactors for generating a large volume of gas from a liquid stream or for producing liquid from a gaseous stream.

BACKGROUND OF THE INVENTION

Systems involving heat or mass transfer are crucial to our industrialized society. Examples of such systems include: power generation, chemical processing systems, and heating and cooling systems. For more than 100 years, scientists and engineers have endeavored to increase the efficiency or reduce the cost of these systems.

Battelle, Pacific Northwest National Laboratories, and others have been using microtechnology to develop Microsystems for carrying out processes that had previously been conducted using far larger equipment. These systems, which contain features of about 1 millimeter (mm) or less, may potentially change heat and mass transfer processing in ways analogous to the changes that miniaturization have brought to computing. Microsystems can be advantageously used in small scale operations, such as in vehicles. Microsystems that can be economically mass-produced can be connected together to accomplish large scale operations.

The production of hydrogen from hydrocarbon fuels, for use in fuel cells, is one example of an application that has been proposed for microsystems. Fuel cells are electrochemical devices that convert fuel energy directly to electrical energy. For example, in a process known as steam reforming, a microsystem can convert a hydrocarbon fuel (or an alcohol such as methanol or ethanol) to hydrogen and carbon monoxide. The hydrogen is fed to a fuel cell that reacts the hydrogen with oxygen (from the air) to produce water and an electric current. The CO could, in a reaction known as the water gas shift reaction, be reacted with water to produce additional hydrogen and carbon dioxide.

A second application has been proposed for delivering hydrogen to fuel cells that involves liquid organic hydrogen carriers (LOHCs). A chemical reactor is operated that removes molecular hydrogen from a LOHC through one or more dehydrogenation reactions, and the hydrogen is consumed in a fuel cell to produce electricity. The spent dehydrogenated LOHC is recovered and returned to a central facility where reverse hydrogenation reactions reload hydrogen onto the LOHC. By this process, the LOHC serves as a carrier for delivering hydrogen to fuel cells or other power systems in distributed applications, such as on fuel cell powered vehicles.

Despite long and intensive efforts, there remains a need for energy efficient and cost effective systems for carrying out operations involving heat or mass transfer. There is also a need for compact systems or reactor systems for generating large volumes of gas from a liquid stream, for producing large volumes of liquid from a gaseous stream, and for performing a reaction between a gaseous stream and a liquid stream.

SUMMARY OF THE INVENTION

In one embodiment of the present invention, an apparatus for generating large volumes of gas from a liquid stream is disclosed. The apparatus includes a first channel through which the liquid stream passes. The apparatus also includes a layer of catalyst particles suspended in a solid slurry for generating gas from the liquid stream. The apparatus further includes a second channel through which a mixture of converted liquid and generated gas passes.

In one embodiment, the apparatus includes a heat exchange channel for heating the liquid stream. A wicking structure can be located in the second channel for separating the gas generated from the converted liquid.

In one embodiment, the liquid is a liquid organic hydrogen carrier and the gas is hydrogen. The catalyst particles comprise, but are not limited to, Pt/Al_2O_3 or Pd/Al_2O_3. The catalyst particles are approximately 2 μm or less.

In one embodiment, the solid slurry consists of catalyst particles held together in a solid-like matrix with a polymer. The polymer is, but not limited to, Teflon.

The catalyst particles comprise at least 60% by mass of the solid slurry and more preferably at least 90% by mass of the solid slurry. In another embodiment, greater than 50% of the catalyst is accessible relative to 100% catalyst particles.

In one embodiment, the apparatus further includes a structural element in the first channel to support the suspended slurry and to improve heat transfer.

In one embodiment, the suspended slurry is less than about 0.5 mm thick. In another embodiment, the suspended slurry is less than about 0.15 mm thick.

In one embodiment, the suspended slurry is in a sheet with an area to thickness ratio of at least 10 mm. In another embodiment, the suspended slurry is in a sheet with an area to thickness ratio of at least 1000 mm. In another embodiment, the suspended slurry is in a sheet with an area to thickness ratio of at least 10,000 mm.

In another embodiment of the present invention, a method of generating a large volume of gas from a liquid stream is disclosed. The method includes passing the liquid stream through a first channel; generating gas by passing the liquid stream through a layer of catalyst particles suspended in a solid slurry; and passing a mixture of converted liquid and generated gas through a second channel.

In another embodiment of the present invention, an apparatus for producing liquid from a gaseous stream is disclosed. The apparatus includes a first channel through which the gaseous stream passes. The apparatus also includes a layer of catalyst particles suspended in a solid slurry for generating liquid from the gaseous stream. The apparatus further includes a second channel through which a mixture of converted gas and generated liquid passes.

In another embodiment of the present invention, a method of producing liquid from a gaseous stream is disclosed. The method includes passing the gaseous stream through a first channel; generating liquid by passing the gaseous stream